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New Hybrid Filter Topology with SPWM for Current Harmonic Elimination and Reactive Power Compensation

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ABSTRACT: It describes about hybrid filter, which remove current distortion produced by the nonlinear system. Hybrid filter topology consisting of an active filter, which is placed after the passive filter's high frequency branch. Purpose of passive filter is to provide a way to fundamental frequency current and neglect other higher order frequency components. Active Power Filter (APF) will compensates high order frequency components. In the Low Pass Filter, current through the capacitor branch can be used for supply to different loads. By using this new topology, we can eliminate the resonance problem occurring between Low Pass Filter and System. The control circuit for active filter has been implemented by using p-q theory(Instantaneous Reactive Power Theory). This paper analyses a comparative study between Sinusoidal Pulse Width Modulation(SPWM) and Hysteresis current controller (HCC) in Hybrid Filter with different constant loads. The new topology enhances current harmonic reduction , Total harmonic distortion reduction, and reactive power compensation .

KEYWORDS: Passive Filter, Active Filter, Hybrid Filter, Total Harmonic Distortion.

I.INTRODUCTION

Nonlinear loads in power systems such as power converters, uninterruptible power supply units, electric furnaces, microwave oven and fluorescent lamps increases the harmonic contents in power grid. It leads to overheating in transformers, overcurrent on equipment neutral connection leads, telephone interference and microprocessor control problems. In this paper we introduce a new idea to take the benefit of removed harmonic wave and make this in to a sinusoidal wave for supplying to different loads. Passive Filter consists of passive elements(L&C), giving short circuit path through X_L and X_C for low frequencies and high frequencies respectively. The harmonic frequencies are eliminated by grounding Low Pass Filter [3] . The main disadvantage of passive filter is that the resonance problem occur between filter impedance and grid impedance. Active filters were introduced to demolish passive filter disadvantages. Its function is to reduce current harmonics and reactive power compensation. Active Filter also have some drawbacks such as high initial cost, high running cost and require high power converter ratings.

Hybrid Filter consists of both active and passive filter [5]. The rating of Active Power Filter in Hybrid Filter should be decreased to 5% or 20% in some cases compared to conventional Active Filter [7]. It gives a new method to take the advantage of distorted power without wasting it through grounding [11]. Low Pass Filter allows the sinusoidal component and obstruct higher frequency harmonics, while Active Filter would eliminate higher frequency harmonics. Here, harmonic source could be mentioned with a universal bridge and MOSFET connected with resistive load .The new topology should be implemented and analysed in Matlab-Simulink program. Here Hybrid Filter has been analysed with both SPWM and hysteresis controller for different constant nonlinear loads.

II.NETWORK REPRESENTATION OF NEW TOPOLOGY

New Hybrid Filter topology consisting of active filter placed after the high frequency branch of the low pass filter. The diagramatic representation of the new hybrid filter topology could be mentioned in Fig.1. The Active Filter could be represented as a current source, while the nonlinear load could be represented as a harmonic source. New hybrid filter topology in single phase , could be represented in Fig.2. The shunt active power filter supplying distorted current of same amount as that of high frequency branch , while in opposite direction to the high frequency branch current.

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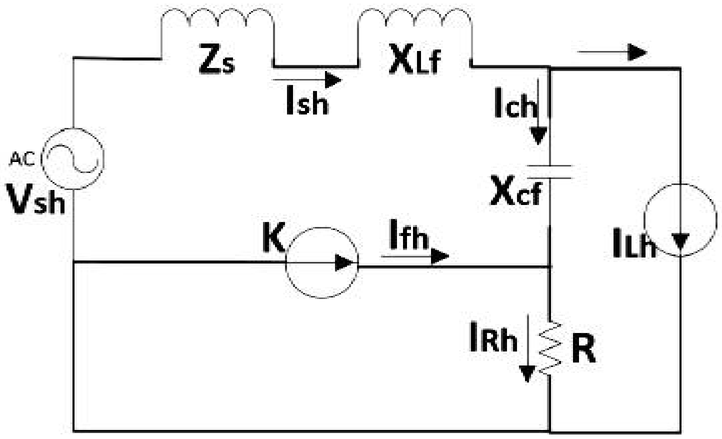

Fig.1.Diagramatic representation of the new Hybrid filter topology

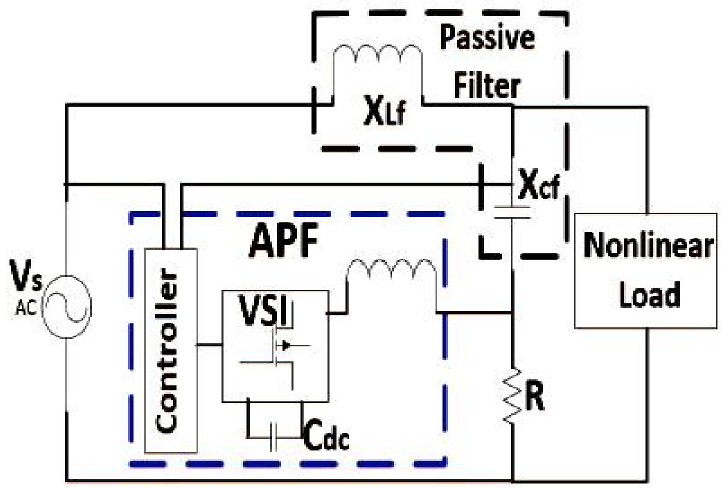

Fig.2.New Hybrid filter topology in single phase

III. P-Q THEORY

This theory could be analysed by using Clarke transformation [6] .The voltages and currents in three phase three wire systems(abc) can be represented in orthogonal coordinates(α,β,O) by using Clarke transformation.

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The Clarke transformation is in the form:

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (2)$$

The real and imaginary powers in α and β coordinates are given by :

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} i_a \\ i_b \end{bmatrix} \quad (3)$$

Where p represents real power flowing per unit time , while q represents reactive power.

$$P = v_\alpha i_\alpha + v_\beta i_\beta = p_{avg} + p_{osc} \quad (4)$$

P_{av} ➡ average power of p.
P_{os} ➡ oscillating power of p.

Reactive power q can be represented as:

$$q = -v_\alpha i_\beta + v_\beta i_\alpha = q_{avg} + q_{osc} \quad (5)$$

q_{av} ➡ average power of q.
q_{os} ➡ oscillating power of q.

The instantaneous active current i_p can be expressed in α and β coordinates as :

$$i_{\alpha p} = \frac{v_\alpha}{v_\alpha^2 + v_\beta^2} p \quad (6)$$

$$i_{\beta p} = \frac{v_\beta}{v_\alpha^2 + v_\beta^2} p \quad (7)$$

Instantaneous reactive current i_q can be expressed in α and β coordinates as :

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$$i_{\alpha q} = -\frac{v_\beta}{v_\alpha^2 + v_\beta^2} q \tag{8}$$

$$i_{\beta p} = \frac{v_\alpha}{v_\alpha^2 + v_\beta^2} q \tag{9}$$

$$\begin{bmatrix} p_\alpha \\ p_\beta \end{bmatrix} = \begin{bmatrix} v_\alpha & i_\alpha \\ v_\beta & i_\beta \end{bmatrix} = \begin{bmatrix} v_\alpha & i_{\alpha p} \\ v_\beta & i_{\beta p} \end{bmatrix} + \begin{bmatrix} v_\alpha & i_{\alpha q} \\ v_\beta & i_{\beta q} \end{bmatrix} \tag{10}$$

Where p_α represents real power in α coordinate and p_β represents real power in β coordinate.

The active power in the three phase system (p) can be represented as :

$$p = p_\alpha + p_\beta = \frac{v_\alpha^2}{v_\alpha^2 + v_\beta^2} p + \frac{v_\beta^2}{v_\alpha^2 + v_\beta^2} p + \frac{-v_\alpha v_\beta}{v_\alpha^2 + v_\beta^2} q + \frac{v_\alpha v_\beta}{v_\alpha^2 + v_\beta^2} q \tag{11}$$

$$i_{L\alpha} = i_{\alpha p} + i_{\alpha q} \tag{12}$$

$i_{L\alpha}$ indicates reference current in α coordinate.

$$i_{L\beta} = i_{\beta p} + i_{\beta q} \tag{13}$$

$i_{L\beta}$ indicates reference current in β coordinate.

$$\begin{bmatrix} i_{refa} \\ i_{refb} \\ i_{refc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} \tag{14}$$

IV. HYSTERESIS CURRENT CONTROL

In this control the comparator compare the output current of inverter with the reference current and the error current will generate. Based on this error current, the controller will generate required triggering pulses for the voltage source inverter. MOSFET switching states will be controlled asynchronously by using this controller. Due to controller action shown in Fig.3(a), the load current will coincide with the reference current.

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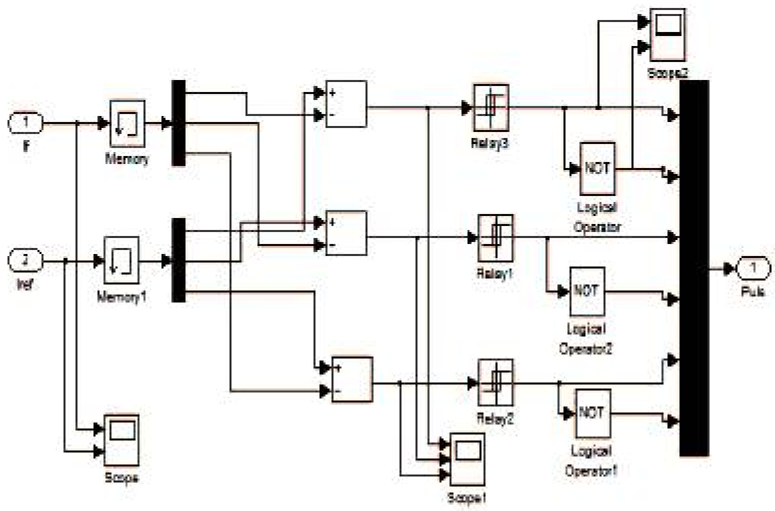

Fig.3(a) .Hysteresis Current Controller

V. SINUSOIDAL PULSE WIDTH MODULATION

PWM signal generated by the PWM generator is used as triggering pulses for the MOSFET.SPWM(Sinusoidal Pulse Width Modulation) is mostly applicable for voltage source inverters in the power electronics field. The comparator compare the output current of inverters and compare with the reference current and error current will generate. Based on this error controller will determine the switching states of MOSFET. The main task of this controller is to coincide the load current with the reference current.

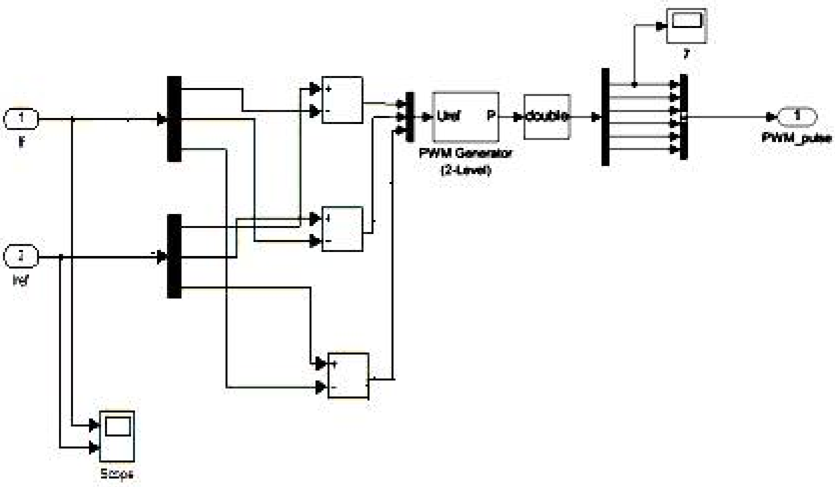

Fig.3(b). SPWM Controller

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VI. SYSTEM CONFIGURATION

Configuration should be represented as follows :

1) Configuration 1 represents generating source and three phase bridge rectifier , MOSFET in series with a resistor , depicted in Fig.4.

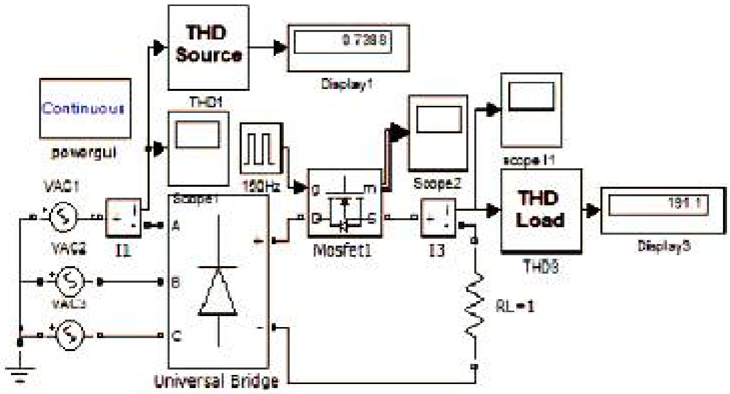

Fig.4. Sample model

2) The configuration 2 represents both passive filter and nonlinear load . The low pass filter eliminate the current harmonics by passing the higher order harmonics through capacitor branch. The circuit can be represented in Fig.5. The current waveform in the capacitor branch should be represented in Fig.6.

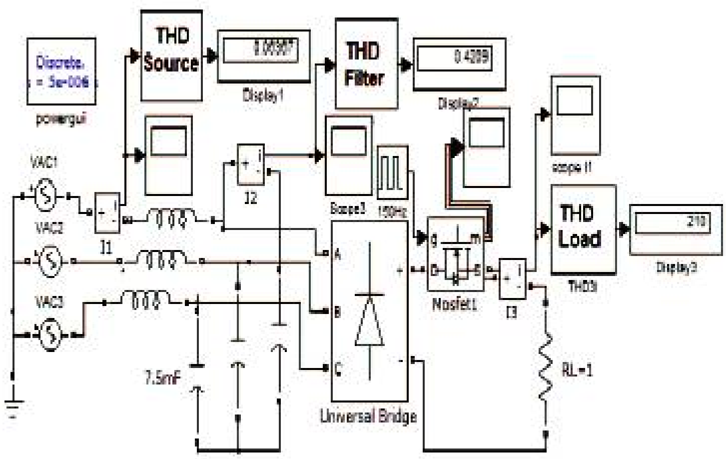

Fig.5.Passive Filter (low pass filter) circuit

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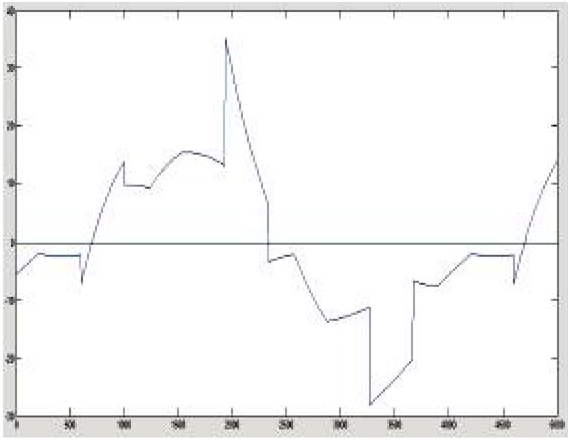

Fig.6.Current in C-branch before implementing active filter

3) Configuration 3 represents active power filter connected after the capacitor in order to eliminate harmonic currents eliminated by Low Pass Filter . It could be represented in Fig.7. The active filter should be implemented and analysed by using p-q theory, Clarke transformation and Hysteresis Current Control .

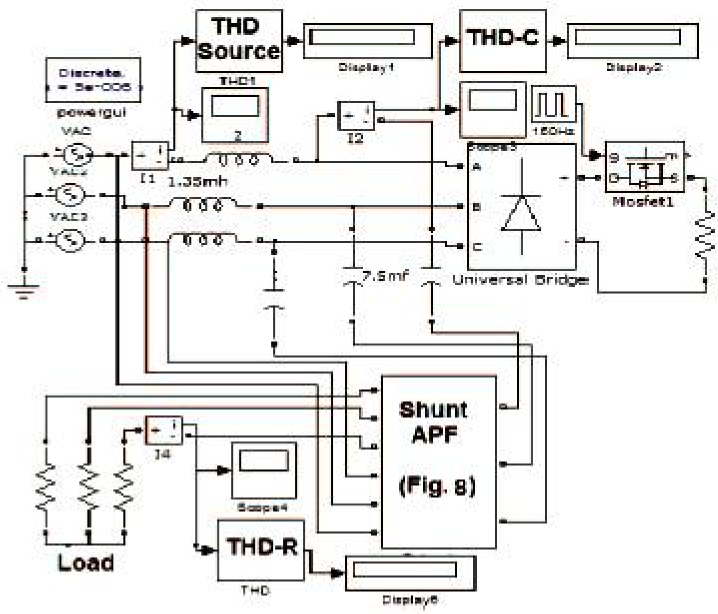

Fig.7. New Topology Of Hybrid Filter

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VII. SPECIFICATION OF THE DESIGN DATA

1) System parameters :

TABLE I
SYSTEM PARAMETERS

V_{Source}	220 AC Volt
System Frequency	50 Hz
Load Resistor	1 Ω
MOSFET Switching Frequency	150 Hz

2) Low pass filter parameters:

TABLE II
LPF PARAMETERS

Inductor	1.35 mH
Capacitor	7.5 mF

3) Active power filter parameters:

TABLE III
APF PARAMETERS

Inductor	0.5 mH
DC link capacitor	2.2 F
Dc link voltage	300 V_{DC}

Fig.8

VIII. SIMULATION RESULTS

	Without filter using constant R load	Without filter using constant RL load	LPF with constant R load	LPF with constant RL load	HAPF (HCC control) with constant R load	HAPF (HCC control) with constant RL load	HAPF (PWM control) with constant R load	HAPF (PWM control) with constant RL load
THD-Source	73.96%	74%	6.52%	68.44%	2.104%	2.04%	2.061%	2.036%
THD-C	-	-	42.54%	42.76%	3.418%	3.317%	3.426%	3.44%
THD-R	-	-	-	-	7.951%	8.159%	7.793%	8.26%

Fig.9.shows the current waveform, when the system is connected to a nonlinear load. The amount of harmonics present in the current waveform is 73.96%.

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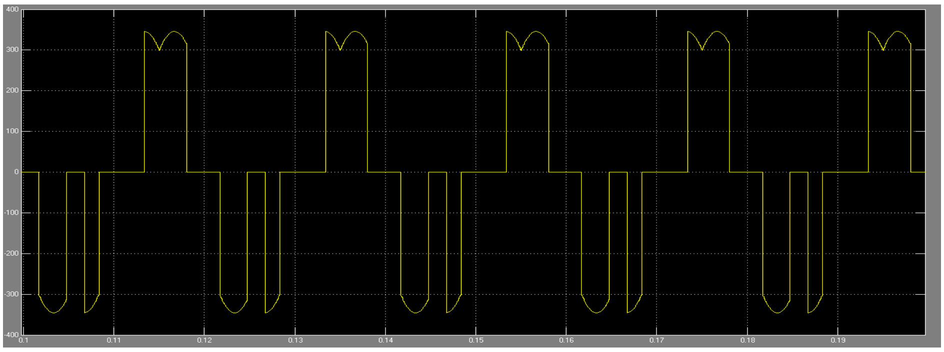

Fig.9. Source wave form ,when connected to nonlinear load

Fig.10.shows the current waveform after the implementation of hybrid filter.By using hybrid filter harmonics of current waveform reduces to 2.104%.

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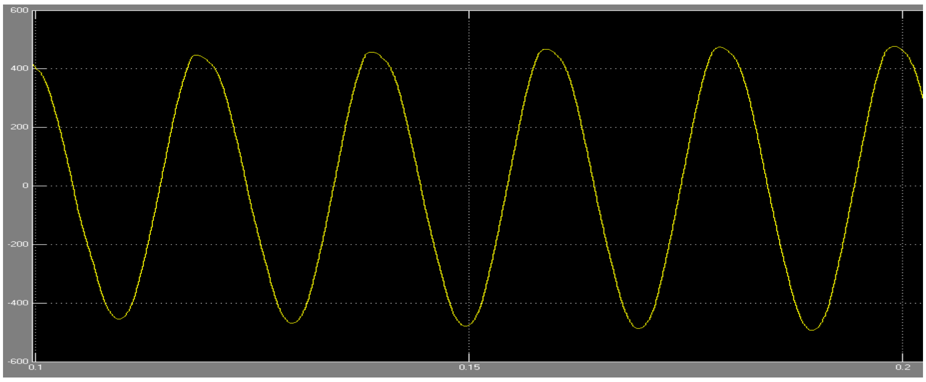

Fig.10. Source waveform with compensation

Fig.11.shows the waveform through resistive branch after the implementation of hybrid filter. It reduces to 7.951% after the compensation.

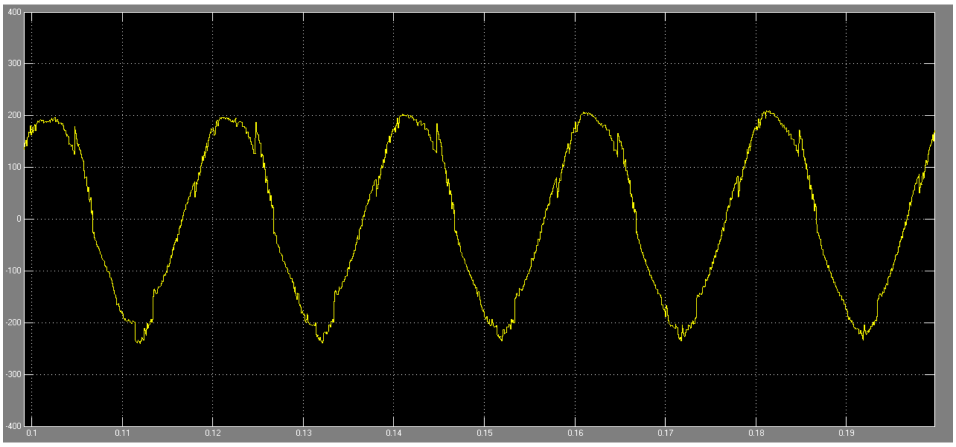

Fig.11. Waveform in resistor branch with compensation

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Ⅸ. CONCLUSION

New Hybrid Filter topology reduces current distortion and compensate reactive power effectively. In case of nonlinear load with constant resistor, Hybrid Filter with HCC reduces current harmonics to 2.104%, while Hybrid Filter with SPWM controller reduces current harmonics to 2.061%. Similarly in case of RL load, Hybrid Filter with HCC reduces current harmonics to 2.04%, while HAPF with SPWM controller reduces current harmonics to 2.036%. From the comparison between Hybrid Filter with HCC and SPWM control for different loads , we can notice that Hybrid Filter with SPWM control effectively reduces current harmonics than HCC.

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